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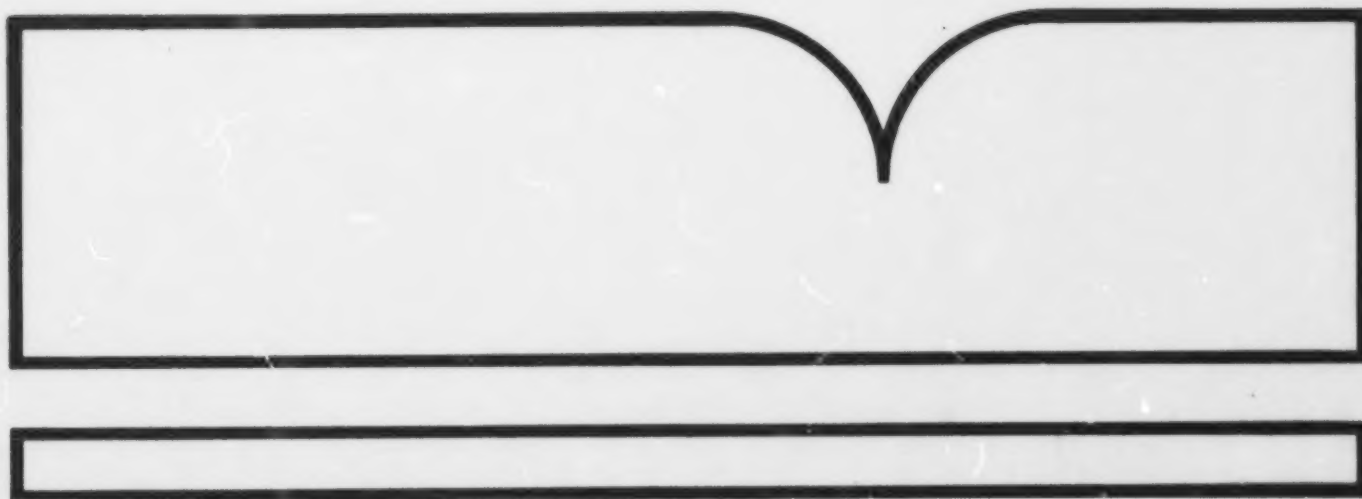
Landfill Gas and Leachate Monitoring
Helena, Montana - A Technical Assistance
Panels Program Report

Fred C. Hart Associates, Inc.
Denver, CO

Prepared for

Environmental Protection Agency
Denver, CO

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Solid Waste

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LANDFILL GAS AND LEACHATE
MONITORING: HELENA, MONTANA
- A TECHNICAL ASSISTANCE PANELS
PROGRAM REPORT

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16. ABSTRACT Leachate contamination of ground water and methane gas production are potential problems associated with solid wastes deposited in landfills. Expanding urban areas may utilize former sites for residential building sites, schools, and parks. This report presents an example of a method which can be used to design a permanent methane gas and leachate monitoring program from a relatively inexpensive preliminary investigation. The monitoring program was conducted on a landfill located within the city limits of Helena, Montana in 1980. A barhole punch survey was conducted to delineate areas of methane gas concentrations and to guide placement of wells. Seven monitoring wells were drilled, logged, and samples were collected. An MSA Model 53 Gascope was used to measure the percent of volume of gas in air and the lower explosive limit of the gas. Water samples were analyzed in a laboratory under selected parameters. Preliminary findings indicated that only a moderate amount of methane gas is, being generated and migration of the gas appeared to be minimal. Leachate from the landfill did not appear to have contaminated the ground water. The report recommends that a long term water quality and methane gas monitoring program be instituted and estimates costs of such a program.		
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1860 Lincoln Street
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Technical assistance by personnel teams. 42 USC 6913

RESOURCE RECOVERY AND CONSERVATION PANELS

SEC. 2003. The Administrator shall provide teams of personnel, including Federal, State, and Local Employees or contractors (hereinafter referred to as "Resource Conservation and Recovery Panels") to provide technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial, and institutional specialists, and the services of such teams shall be provided without charge to States or local governments.

This report has been reviewed by the Project Officer, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Project Officer: William Rothenmeyer, EPA Region VIII

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LANDFILL GAS AND LEACHATE MONITORING HELENA, MONTANA
ENVIROMENTAL PROTECTION AGENCY REGION VIII



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I. EXECUTIVE SUMMARY

Potential Problems Associated with Municipal Landfills

Leachate contamination of ground water and methane gas production are potential problems associated with solid wastes deposited in municipal landfills. Ground water contamination and methane gas generation may present particularly acute problems in older landfills which were originally sited on the outskirts of urban areas. As the urban areas expand, former landfill sites become attractive for building sites and may be used for residences, schools, and parks. Urban expansion onto abandoned landfill sites increases the likelihood that contaminated ground water and/or methane gas may jeopardize the health and well being of people living in or using the areas. Analyzing and eliminating the potential hazards posed by landfill areas situated within urban boundaries may be difficult for small or medium size cities which may not have the resources or expertise to solve these problems. This report presents an example of how ground water contamination and methane gas generation problems from urban landfills may be identified and monitored with relatively little expense.

The Helena, Montana Case

The City of Helena, Montana and the Montana Department of Health and Environmental Sciences' Solid Waste Management Bureau (SWMB) are concerned about the possible existence of ground water contamination and methane gas migration from a landfill located within the Helena city limits.

The State of Montana requested the assistance of the Environmental Protection Agency (Region VIII) to identify the existence and extent of ground water contamination and methane gas production from the Helena site. EPA granted the request under authority of Section 2003 (Panels) of the Resource Conservation and Recovery Act which states "the Administrator shall provide teams of personnel, including Federal, State and local employees or contractors to provide technical assistance on solid waste management, resource recovery, and resource conservation." Fred C. Hart Associates, Inc., EPA Region VIII's designated Panels contractor performed the study. Tasks which were performed to satisfy this request include the following:

- o preliminary identification of landfill methane gas hazards
- o preliminary identification of ground water contamination by leachate from the sites
- o identification of the threats to public health and the environment posed by ground water contamination and methane gas migration
- o discussion of the potential for the recovery of methane from the landfill for use as an energy fuel

The Helena landfill site has been used for the disposal of solid waste for about fifty years. Open burning was the principal waste disposal method at the site prior to 1970. Burning was halted in 1970 and sanitary landfill practices began. These practices consisted of the placement and compaction of waste in large cells. Refuse deposited at the site since 1970 consists mostly of household wastes. Construction debris has been deposited in the southern section of the landfill site. Household refuse may have been placed above the construction debris. The southern section has been covered with soil and reclaimed. The waste deposited at the site is covered daily. The Helena landfill is in compliance with all local, State and Federal regulations.

A site monitoring project was established in cooperation with the State of Montana and City of Helena officials. A barhole punch survey was performed initially to delineate areas of methane gas concentration for the positioning of permanent monitoring wells. The barhole punch test was conducted within the landfill boundaries and on adjacent areas. Monitoring wells were drilled following the completion of the barhole punch survey. Gas and ground water samples were taken from the wells for laboratory analysis.

A single set of samples was collected and analyzed for methane and leachate levels. This preliminary analysis was performed to establish the general parameters of methane and leachate problems.

Initial data obtained from the barhole punch survey and the monitoring wells are presented and analyzed in this report. Recommendations for the

mitigation of methane and leachate hazards and the potential for using methane as a fuel are included.

Summary of Conclusions

Methane Gas Generation. Preliminary findings indicate that only a moderate amount of methane gas is being generated within the inactive landfill area. The migration of methane gas from the landfill appears to be minimal. Recovery of the methane gas for use as a fuel is not economically feasible at the present time. The lack of volume of fill precludes the installation of any methane recovery system. Automated methane monitoring systems (alarms) should be installed in two buildings located near the landfill site (YMCA and Armory) to ensure that methane levels do not present a safety hazard.

Leachate generation. Leachate from the Helena landfill does not appear to have contaminated ground water to a discernible degree or to pose a human health hazard. Preliminary results from tests on ground water samples obtained from wells upgradient of the landfill site, within the landfill site, and downgradient from the landfill site indicate that leachate migration from the disposal site has not occurred.

Conclusions drawn from this initial effort are preliminary and not based on a statistically significant number of samples. A long-term monitoring program should begin on the landfill site to verify the results of this study. Results from further sampling and testing should be used to design permanent methane gas and leachate monitoring programs. Discontinuing the operation of the Helena landfill due to its proximity to an urban area will not mean the cessation of methane gas and leachate generation and migration problems. Recommendations contained in this report apply regardless of the operational status of the Helena landfill.

II. INTRODUCTION - METHANE AND LEACHATE PRODUCTION IN MUNICIPAL LANDFILLS

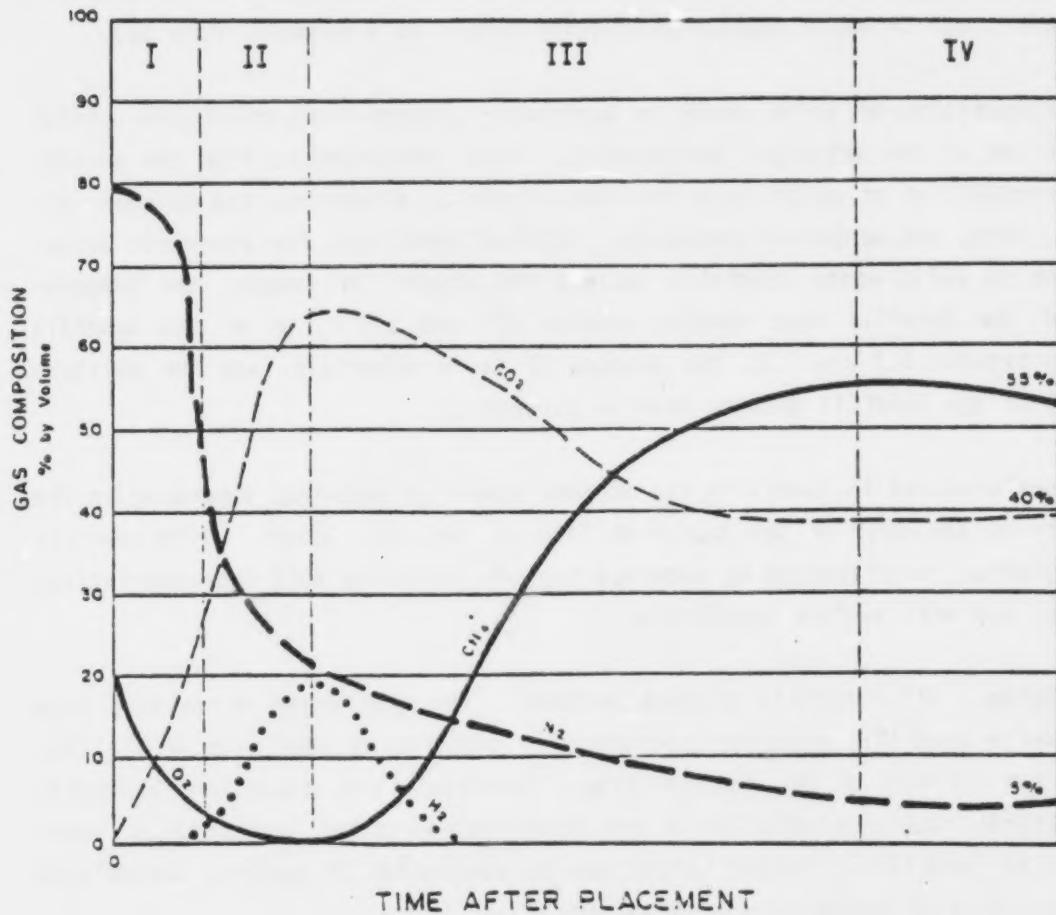
Characteristics of Methane in Landfills

Stages of decomposition in landfills. Municipal landfills typically contain a mixture of solid wastes including paper, wood, plastics, glass, living organisms, and ferrous and non-ferrous metals. After the waste is deposited, microbial processes begin to break down the organic matter. Moisture and warm temperatures accelerate the microbial decomposition of organic matter. Most sanitary landfills have moisture levels around 25 percent. Optimum moisture levels for methane production in landfills range between 60 to 80 percent (1). Temperatures within landfills during the anaerobic decomposition stages range between 90° and 110° F. Ambient air temperatures below 50° F. result in significant decreases in methane production (1). However, methane production can occur at temperatures lower than 50°F. Frozen ground surfaces increase the potential for methane to move laterally beneath the landfill surface and may contribute to methane problems which are usually associated with warmer temperatures.

There are four principal stages in organic decomposition in solid waste landfills (see Figure 1). The first or aerobic stage requires oxygen. During this stage organic decomposition is an exothermic reaction which liberates additional heat to fuel further decomposition. The availability of oxygen also determines the rate of organic decomposition. Normally, microbial action in solid waste landfills rapidly depletes available oxygen supplies unless supplemental oxygen is introduced. The absence of oxygen halts the oxidation process.

The latter three, or anaerobic (oxygen-free), stages occur as the oxygen supply in the landfill mass is depleted. Stage II, the first part of the anaerobic decomposition, occurs without the production of methane. Carbon dioxide and hydrogen are the principal end products produced during this phase. Methane is produced in increasing quantities in Stage III. Stage III begins six months to several years after initial landfill placement (4). The fourth stage of decomposition is marked by the relatively steady-state production of methane.

FIGURE 1. LANDFILL GAS PRODUCTION DURING THE FOUR PRINCIPAL STAGES OF SOLID WASTE DECOMPOSITION



- I. AEROBIC
- II. ANAEROBIC, NON-METHANOGENIC
- III. ANAEROBIC, METHANOGENIC, UNSTEADY
- IV. ANAEROBIC, METHANOGENIC, STEADY

Source: Farquhar and Rovers (3).

Many site-specific variables determine the rates of solid waste decomposition and the onset of the decomposition stages. Tests on a fixed volume of refuse in a sealed tank show that over two years are necessary to achieve the anaerobic stage IV where methane production occurs at a constant rate (2).

Decomposition of solid waste in anaerobic (oxygen-free) conditions yields methane gas as the principal end-product. Other end-products from the anaerobic decomposition of solid waste includes alcohols, aldehydes, and sulphur, nitrogen, iron, and manganese compounds. Optimum conditions for anaerobic decomposition in solid waste landfills include the absence of oxygen, the temperature of the landfill mass ranging between 85° and 100°F, pH of the landfill ranging between 6.8 and 7.2, the absence of toxic materials, and the moisture content of the landfill greater than 40 percent (1).

Gases produced in landfills can migrate upward or outward, depending on the porosity of the soil or the impermeability of the soil cover. Site-specific gas migration is influenced by numerous factors including soil characteristics, climate, and soil surface conditions.

Hazards. All landfills produce methane. The generation of methane from solid waste landfills presents a potentially significant hazard to people living in the vicinity of the disposal site. Potential fire, explosion, asphyxiation hazards, and vegetation kills are associated with the production of methane gas in landfills. Public safety may be endangered if methane accumulates in combustible or explosive concentrations.

Methane is explosive in concentrations in the atmosphere of between five and fifteen percent (see Figure 2). Concentrations of methane lower than five percent are not enough to support an explosion. Concentrations of methane in the atmosphere higher than fifteen percent mean that too little oxygen is available to support an explosion. The five to fifteen percent range is called the methane flammable envelope (see Figure 3). An enclosed combustion chamber or confined area where methane can collect are required before methane will explode.

Landfill methane is usually produced in concentrations above the explosive range. Landfill methane will always pass through the explosive range when dil-

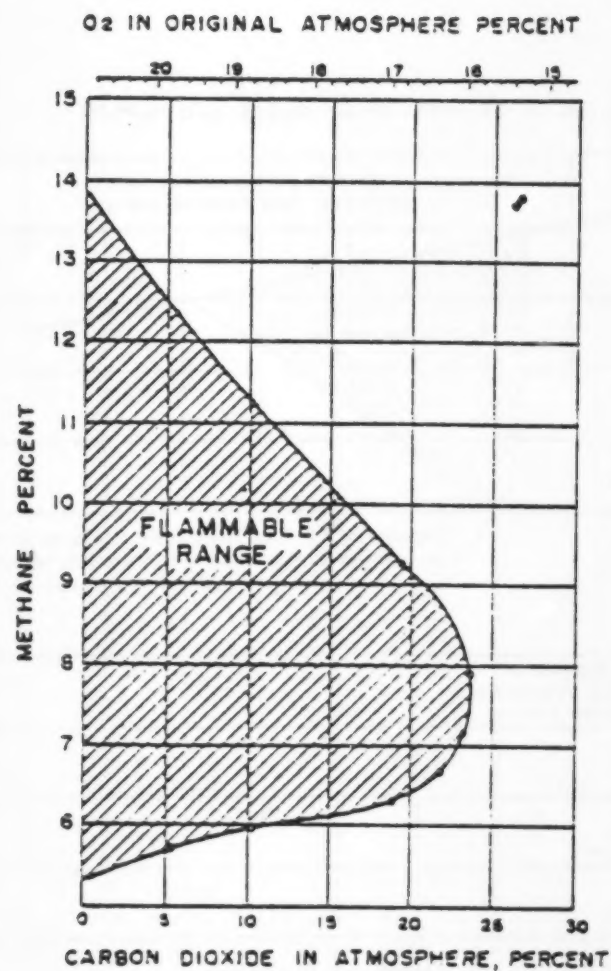


FIGURE 2. LIMITS OF FLAMMABILITY OF METHANE
IN MIXTURES OF AIR AND CARBON DIOXIDE:
THE METHANE EXPLOSIVE ENVELOPE

Source: Farquhar and Rovers (3).

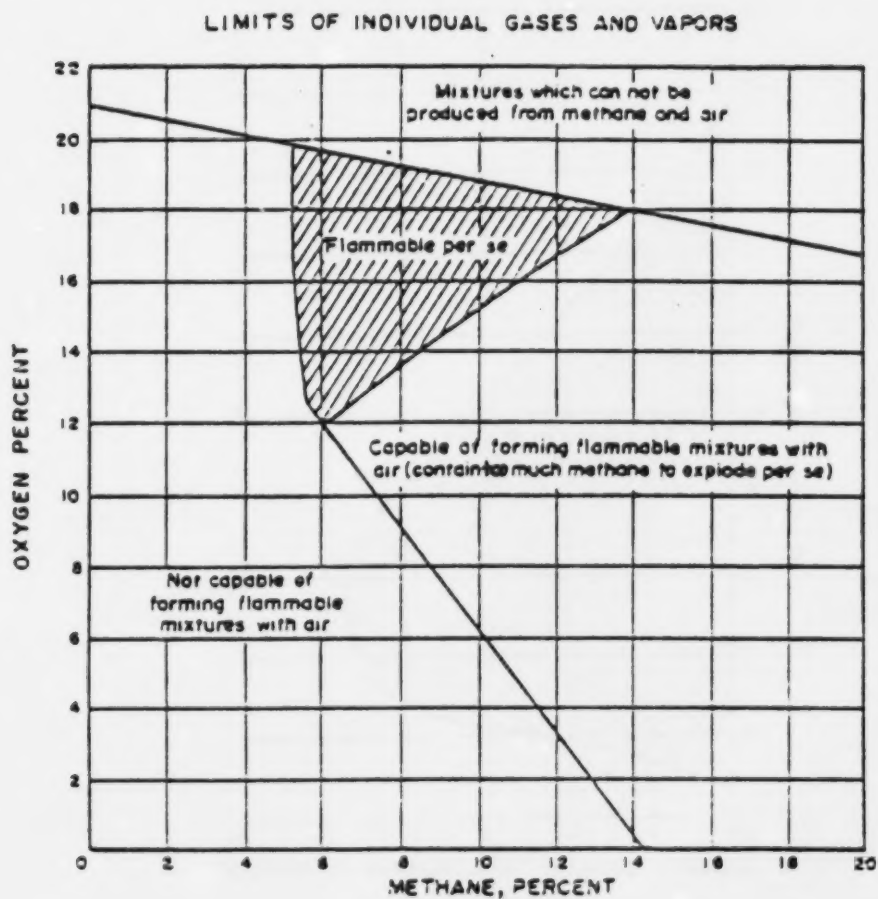


FIGURE 3. RELATIONSHIP BETWEEN LEVELS OF GASES, AND FLAMMABILITY OF MIXTURES OF METHANE, AIR, AND NITROGEN: METHANE'S ENVELOPE OF EXPLOSIVITY

Source: Farquhar and Rovers (3).

uted with air. There is usually no explosion when methane concentrations are within the explosive range because of the lack of a flame source (spark, etc.) in the landfill.

Explosions have been known to occur because of landfill methane. Explosions occur most frequently when methane concentrates in poorly ventilated areas. Methane can migrate subterraneously great distances through permeable media - porous soils, trench backfills, utility or drainage corridors - and collect in poorly ventilated structures, sanitary and storm sewers, etc.

Various site specific conditions will determine the level of the methane explosion hazard. These include the type of landfill cover, type of surrounding soil, amount of methane produced, ambient air temperatures, precipitation and landfill moisture content, air pressure, atmospheric turbulence, and the presence or absence of conduits or barriers (1).

Production of Methane in Landfills. An anaerobic condition in a landfill is the most critical factor in determining the production of methane. Waste treatment (compaction, shredding, deposition in cells) accelerates the reduction of available oxygen and increases the timing of anaerobic conditions. However, if methane is recovered faster than it is generated, air may infiltrate through the landfill cover and slow the generation of methane. The infiltration of air into the landfill mass usually occurs in landfills which are unable (not deep enough) to support a high methane recovery rate.

The depth of the landfill is another important factor in determining the production of methane. Landfills with depths greater than 100 feet are best able to support an adequate methane recovery system. Generally, 30 to 40 feet of fill are necessary to support a minimum, but uniform, methane production and recovery system (5, 6, 7). Compaction tends to lower initial landfill gas and leachate production rates by decreasing the landfill waste volume and increasing the waste density. This results in a longer period of methane and leachate production.

Potential for Methane Migration. Methane will normally migrate upward because of its relatively low density. However, when upward movement is restrict-

ed, the gas will tend to migrate laterally along paths of low resistance to a location where upward movement is possible. Conditions which reduce the potential for upward movement increase the possibility of horizontal migration. Frost or heavy precipitation tend to fill or close the soil voids, causing the soil to become less permeable and increase the potential for lateral gas movement. Layers of clay or other impermeable materials placed near the surface of the landfill or within the landfill will tend to increase lateral gas migration. The potential for methane migration is roughly estimated at 10 feet of lateral movement for each foot of landfill depth (5, 8).

The migration of gas beyond the limits of landfills is a common occurrence. Uncontrolled migration of methane gas is capable of producing hazardous conditions in structures, excavations and underground conduits. Gas migration occurs through convection and diffusion. Convection is the movement of gas in response to pressure gradients; diffusion is the movement of gas from areas of higher gas concentration to areas of lower concentrations.

Gas flows through a soil mass in a fashion similar to water movement. Soils having a high void ratio, such as sands and gravels, are conducive to gas migration. Low permeability soils, such as silts and clays, tend to restrict gas migration. The actual amount and extent of gas migration from landfills is largely dependent on the hydrogeologic environment of the site. Landfill constructed in sand and gravel environments have more vertical and lateral movement of gases than landfills built in an impervious soil environment. Since methane is relatively insoluble in water, the presence of ground water significantly decreases gas migration.

Natural ventilation of any methane gas produced occurs to varying degrees during the summer months. Such natural ventilation will be enhanced by the coarse-grained composition of the cover soil. However, potential for off-site migration will tend to increase during the winter months due to frost closing the voids in the cover material which limits vertical ventilation and encourages horizontal migration.

Migrating methane gas may enter structures through cracks in the floor slabs or foundation walls, joints in the floor slab or around structural mem-

bers, or through conduit openings for sanitary, water, and electrical services. The perviousness of service conduit backfills may actually aid methane migration.

Controlling Methane Migration. Methane gas migration can be controlled by two methods: 1) impermeable barriers and 2) ventilation systems. Barrier systems require the placement of impervious liner materials to block or seal in the flow of gas. Ventilation systems create a controlled flow of methane from the landfill into the atmosphere.

Impermeable barriers consist of clay or synthetic lining materials and are usually installed along the perimeter of the landfill. Natural soils, such as saturated clays, may furnish effective barriers to methane migration. Impermeable barriers may be combined with gravel-filled trenches or wells between the barrier and the landfill. These granular zones are installed to promote the vertical migration of methane into the atmosphere. Barriers are most effectively installed during the development of new landfill sites.

Passive ventilation systems rely on naturally occurring pressure or diffusion gradients to induce exhaust. Highly permeable materials are placed in the path of gas flow and the gas flow is directed to a point of controlled release. Active ventilation systems are normally the most effective methane migration control system in existing landfills. Wells, drilled at positions to intercept migrating gases, consist of perforated pipe extending through the depth of the landfill and backfilled with sand. Wells placed under a negative pressure gradient induce gas flow. Wind turbines placed on top of the perforated pipes or large pumps with high flow volumes have been used with varying success to provide the necessary negative pressure gradient.

Recovery and Use of Methane from Landfills. An active methane production environment usually requires the following conditions: high organic content of the waste, low-oxygen levels, adequate moisture levels, neutral pH, adequate subsurface temperatures, nutrient availability, and large concentrations of

anaerobic stage of decomposition, gas concentrations normally range between 40 to 50 percent carbon dioxide and between 45 to 70 percent methane (4, 5, 6). Average heating values for recovered methane gas from landfills are typically between 400 and 600 British thermal units (Btu) per standard cubic foot (scf). The recoverability of methane gas from landfills depends upon the combination of gas production factors mentioned above and the time elapsed since the disposal of the solid waste. Reports have shown that methane gas in landfills may be generated at rates between 0.06 and 0.23 scf/pound of solid waste per year (6).

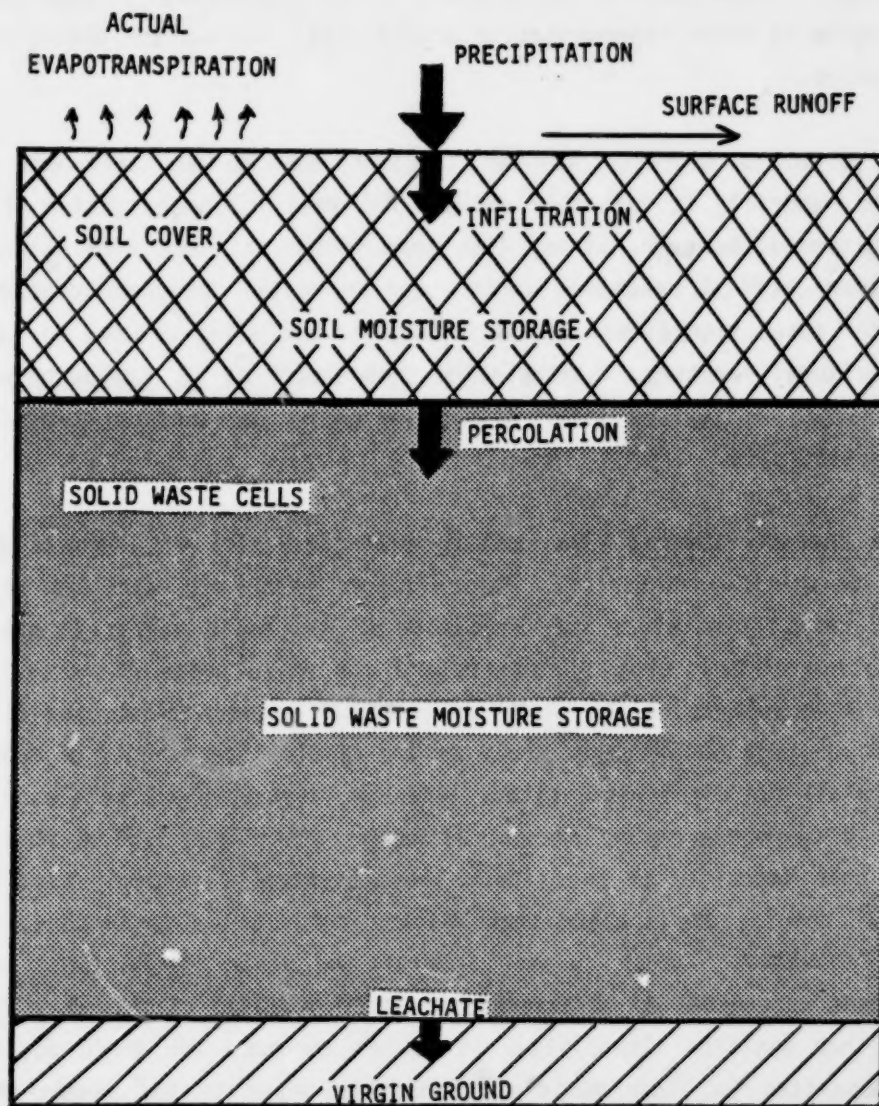
Production of Leachate in Landfills

Leachate is produced in solid waste landfills by the introduction of supplemental moisture, either through the infiltration of precipitation, or the contact of the wastes with ground or surface waters. In a properly sited landfill, however, the infiltration of precipitation will be the primary manner in which water can enter the body of the landfill. Solid waste decomposition also produces water as one of its principal end-products, although a certain amount of water will be absorbed by the solid waste as it decomposes.

Water Balance Formula. The formation of leachate within a landfill can best be illustrated by EPA's water balance formula for estimating percolation rates through a landfill (9). Figure 4 illustrates the components of the water balance formula. The water balance concept is based upon the relationship between precipitation, evapotranspiration, surface runoff, and the water storage characteristics of both the overlying soil and the solid waste material. Percolation will occur under those conditions where the amount of infiltrating water (derived from either direct precipitation or surface water which flows onto the landfill from adjoining higher ground) exceeds the amount necessary to satisfy actual evapotranspiration and the soil and solid waste water retainment capabilities. This water which percolates through the landfill can move downward, under gravity, into the native soil beneath the landfill. The concept is illustrated schematically in Figure 4.

Ground Water Contamination. Ground water contamination from landfill leachate is a distinct possibility depending on how close the water table exists

FIGURE 4. WATER BALANCE AND LEACHATE PRODUCTION IN LANDFILLS



Source: EPA (9)

below the base of the landfill. Although the water-balance method is useful for predicting the quantity of percolate which can migrate downward from a landfill, it does not allow for a prediction of the actual quality of the water (either in terms of concentration or constituents present) following contact with the waste. Water quality can only be determined through a sampling and analysis program in which representative ground water samples are obtained from monitoring wells.

As the percolate migrates downward through the various soil and waste layers in the landfill, it generally shows a net gain in concentration of dissolved constituents; however, it may lose some individual ions from cation exchange or other chemical reactions which occur en route. Leachate degradation of groundwater poses significant health hazards if the water is used for domestic or agricultural purposes. Contaminated groundwater may be tapped by wells, may be discharged to surface water or may emerge on the surface downgradient from the disposal site.

Leachate Characteristics. The quality characteristics of leachate depend upon many site-specific variables. Major factors which determine the make-up of leachate are: 1) time since the deposition of the solid waste; 2) quantity and distribution of moisture; 3) temperature; 4) solid waste characteristics (the principal components of the waste and disposal methods used); and 5) geology and geohydrology of the site. Many of the chemical components of leachate are common to all municipal waste sites. However, certain heavy metals or synthetic organic compounds may be present if wastes other than typical municipal refuse have been deposited at the site. These atypical compounds, usually of an industrial origin, may include such diverse compounds as pesticides, PCB's and organic solvents. Under current Federal and State regulations, wastes which have been determined to be hazardous must be disposed of in secure facilities other than municipal landfills. It is not uncommon for these wastes to have been deposited in older municipal landfills prior to the advent of the regulations.

Table 1 shows the typical chemical constituents found in landfill leachate, along with ranges of concentrations observed by several researchers. Several

TABLE 1. CHEMICAL CHARACTERISTICS OF MUNICIPAL LANDFILL LEACHATE

Constituent	Range [*] (mg/l)	Range [†] (mg/l)	Range [‡] (mg/l)	Leachate [§]	
				Fresh	old
Chloride (Cl)	34-2,800	100-2,400	600-800	742	197
Iron (Fe)	0.2-5,500	200-1,700	210-325	500	1.5
Manganese (Mn)	.06-1,400	--	75-125	49	--
Zinc (Zn)	0-1,000	1-135	10-30	45	0.16
Magnesium (Mg)	16.5-15,600	--	160-250	277	81
Calcium (Ca)	5-4,080	--	900-1,700	2,136	254
Potassium (K)	2.8-3,770	--	295-310	--	--
Sodium (Na)	0-7,700	100-3,800	450-500	--	--
Phosphate (P)	0-154	5-130	--	7.35	4.96
Copper (Cu)	0-9.9	--	0.5	0.5	0.1
Lead (Pb)	0-5.0	--	1.6	--	--
Cadmium (Cd)	--	--	0.4	--	--
Sulfate (SO ₄)	1-1,826	25-500	400-650	--	--
Total N	0-1,416	20-500	--	989	7.51
Conductivity (Mmhos)	--	--	6,000-9,000	9,200	1,400
TDS	0-42,276	--	10,000-14,000	12,620	1,144
TSS	6-2,685	--	100-700	327	266
pH	3.7-8.5	4.0-8.5	5.2-6.4	5.2	7.3
Alk as CaCO ₃	0-20,850	--	800-4,000	--	--
Hardness tot.	0-22,800	200-5,250	3,500-5,000	--	--
BOD ₅	9-54,610	--	7,500-10,000	14,950	--
COD	0-89,520	100-51,000	16,000-22,000	22,650	81

*Office of Solid Waste Management Programs, Hazardous Waste Management Division. An environmental assessment of potential gas and leachate problems at land disposal sites. Environmental Protection Publication SW-110 of. [Cincinnati], U.S. Environmental Protection Agency, 1973. 33 p. [Open-file report, restricted distribution.]

†Steiner, R. C., A. A. Fungaroli, R. J. Schoenberger, and P. W. Purdom. Criteria for sanitary landfill development. Public Works, 102(2): 77-79, Mar. 1971

‡Gas and leachate from land disposal of municipal solid waste; summary report. Cincinnati, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, 1975. (In preparation.)

§Brunner, D. R., and R. A. Carnes. Characteristics of percolate of solid and hazardous waste deposits. Presented at AWMA American Water Works Association 94th Annual Conference, June 17, 1974. Boston, Mass. 23 p.

Source: EPA (11).

inorganic constituents (metallic and non-metallic) are present in typical landfill leachate. The organic component of landfill leachate is usually characterized indirectly, using general analyses such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), and, in some instances, total organic carbon (TOC). Although the three tests do not differentiate and identify individual chemical species, they do provide a reasonable indication of the amount of organic matter present in the leachate solution.

In addition to the chemical constituents present in landfill leachate, the presence of bacteria and viruses has also been reported. Those organisms identified include fecal coliform, fecal streptococci, and poliovirus.

Leachate Parameters. The Colorado State Department of Health (CDH) has assembled a list of parameters which the CDH considers typical of landfill leachate (9). These are shown in Table 2. The list has been prepared as a guideline for leachate and ground water monitoring programs, where the principal effort is directed at identifying the presence of off-site leachate migration. Since the list has been developed as a guideline, the parameters should not be viewed as the necessary minimum which must be monitored in a landfill investigation. Abbreviated parameter lists may also be quite satisfactory. Selection of appropriate parameters to test will depend on site-specific requirements.

Leachate Monitoring. A typical leachate monitoring program uses ground water samples from monitoring wells located at various distances from the landfill site. The samples are tested for the levels of representative constituents of leachate. The constituents included in the program are typically selected based on consultation with published lists of parameters, such as those which appear in Tables 1 and 2 of this report. Other considerations in this selection process include:

- o A knowledge of the types of wastes disposed at the site. This information is particularly important if a waste is present which would produce contaminants which are not characteristic of municipal landfill leachate. This information is usually not available in any detail.

TABLE 2
CHEMICAL TESTS EMPLOYED BY THE COLORADO DEPARTMENT OF HEALTH ON
LANDFILL LEACHATE.

1. BOD
2. COD
3. pH
4. Ammonia ($\text{NH}_4\text{-N}$)
5. Nitrate ($\text{NO}_3\text{-N}$)
6. Conductivity
7. Ortho-Phosphate (O-PO_4)
8. Cadmium
9. Zinc
10. Copper
11. Nickel
12. Total Alkalinity
13. Free CO_2
14. Potassium
15. Iron
16. Manganese
17. Total Hardness
18. Boron
19. Lead
20. Chromium
21. Chloride
22. Sulfates
23. Sodium

SOURCE: COLORADO DEPARTMENT OF HEALTH (10).

- o Budget constraints, which would limit the amount of funds available for analytical purposes. In this case, the selection process would limit the number of constituents to those which would be absolutely necessary.

The number of monitoring wells are selected so that at least one well is located upgradient of the landfill site; one well is located at the downgradient edge of the fill area; and three wells are located downgradient from the site to detect potential leachate migration off-site (11). The size of the landfill, the hydrogeologic environment, and budgetary restrictions are the primary factors which will dictate the actual number of wells used. Every effort should be made to have a minimum of five wells at each landfill (11). Locations of the wells, their placement sequence, and the need for additional wells depend upon the site-specific conditions present at each landfill.

III. STUDY AREA DESCRIPTION

Helena Landfill Site

The City of Helena landfill is situated northwest of the roadway intersection of Lyndale Avenue and Last Chance Gulch Street in the central part of the city. The site is bounded on the west by a small ridge upon which Carroll College buildings are located and on the north by the Burlington Northern Railroad tracks. The site is owned by the Burlington Northern Railroad and is leased to the City. Figure 5 depicts a layout of the site.

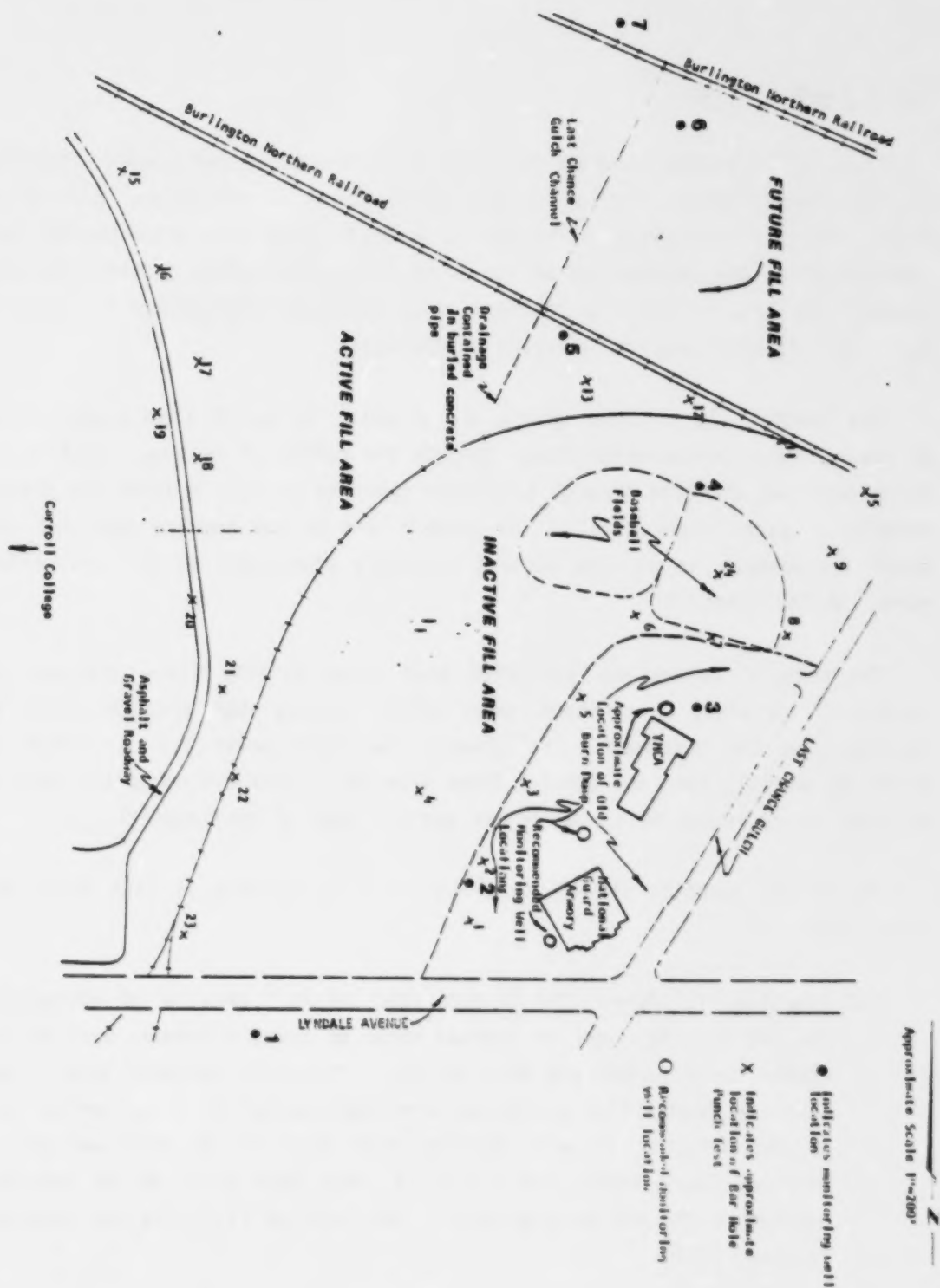
The landfill is situated within the alluvial valley of Last Chance Gulch, an intermittent stream which flows through the center of Helena. Last Chance Gulch has been diverted through a 60-inch concrete conduit beneath the present landfill. Water flows both in the conduit and in the bedding material upon which the conduit rests. The conduit presently discharges at the northwestern border of the landfill.

The City of Helena has indicated that other utility lines transect the landfill, including a sanitary sewer which crosses the property from the southwest to the northeast. It appears that this sewer line is below the existing landfill and that service lines from this sewer extend to the YMCA and National Guard Armory buildings on the eastern edge of the landfill.

The Helena landfill site is best described by dividing it into three distinct areas:

- (1) Inactive Fill Area: The 17-acre inactive fill area, which encompasses the old burning dump, is located north of Lyndale Avenue, west of Last Chance Gulch Street and east of the north-south railroad spur. When sanitary landfilling practices were implemented in 1970, twelve acres of the original 17 acre burning dump were filled with wastes. A National Guard Armory and a Y.M.C.A. have been built on the remaining acreage of the old burning dump. The inactive fill area was completed in June, 1977.

FIGURE 5. THE HELENA LANDFILL SITE SHOWING BARHOLE PUNCH TEST AND MONITORING WELL LOCATIONS



The inactive landfill averages 25 feet in depth and is overlain by approximately two to four feet of sandy, clayey, alluvial soils. An estimated 162,000 tons of municipal refuse were deposited in the landfill from 1970 to June, 1977. An equal or greater tonnage of demolition waste was also dumped in the southern one third of the landfill during this period. No figures are available on the amount of wastes burned prior to 1970.

Paint solvents, which were received at the rate of six barrels a week, were mixed with the construction debris. The disposal of solvents was discontinued after the first several years of operation. The site has also been used on occasion for disposal of snow and ice which had been removed from city streets.

Twelve acres of landfill area have been graded, resulting in a fairly flat ground surface which slopes gently to the north. Two baseball fields have been constructed in the northern portion of this area. Vegetation consists primarily of weeds on the majority of this site with the exception of a landscaped area along Last Chance Gulch Street north of the YMCA building.

- (2) Active Fill Area: This area is bounded by an east-west track of the Burlington Northern Railroad on the north, the north-south railroad spur on the east, and an asphalt and gravel roadway on the west. Landfill operations are currently in progress in this portion of the site, resulting in an irregular ground surface. The present landfill practice consists of excavating cells approximately 75 to 100 feet wide and eight to twelve feet deep in the natural soils. Refuse delivered to these cells is randomly dumped, leveled and compacted with a self-propelled compactor. It appears that no intermediate soil blankets are placed between the layers of refuse placed in the cell. Soil barriers are left between adjacent cells. This portion of the site has very little vegetation. Daily cover of the waste is provided.

Access to the site is limited to six days per week, Monday through Saturday. The site has a gatehouse with scales and all vehicles are weighed to determine the quantity of waste received at the site. Approximately 30,000 tons of waste are received at the site annually and it is estimated that in January 1982, the expected closing date of this portion, 159,000 tons of municipal refuse will have been deposited. The majority of these wastes are generated within the city limits of Helena. No user fee is assessed to city residents; rather, an annual collection assessment is charged. Citizens or commercial establishments which are not assessed collection fees must pay a user fee at the gate.

Four persons are employed at the landfill - a gate keeper, two equipment operators, and a laborer. The site is maintained primarily by a bulldozer and a landfill compactor. A scraper is also available for excavating trenches and stockpiling cover material. The landfill is in full compliance with all local, State, and Federal standards.

- (3) Future Fill Area: The future fill area is located west of Last Chance Gulch Street and between the two east-west Burlington Northern Railroad tracks. This area is expected to have an 18-year life beginning in January, 1982 with an average annual waste load of 35,000 tons per year. It is approximately 20 to 25 feet lower than the landfill mass to the south. The ground surface slopes gently down to the north with a maximum difference in elevation on the order of 5 to 10 feet. In this area, Last Chance Gulch leaves the 60-concrete conduit beneath the landfill, and returns to its natural channel. The channel had a moderate amount of flow at the time of the study. Vegetation consists of grasses, weeds and numerous deciduous trees along the drainage way.

Landfill Site Geology

An independent assessment of the geological and geotechnical data associated with the Helena landfill site was beyond the scope of this study. Site geology information, which follows, was obtained from a memo prepared by Mr. Kenneth L. Waesche, geologist for the State of Colorado Department of Health

(10). Mr. Waesche prepared a monitoring plan for the Helena landfill as part of a peer match visit (an EPA program which seeks to bring problem-solving expertise to areas which do not have that capability).

The alluvial soils of Last Chance Gulch consist of interbedded silts, sands, gravels and cobbles which extend to depth of approximately 30 to 35 feet. The alluvium has been thoroughly worked as a placer deposit and consequently is more uniformly graded at those locations where such operations occurred. Research conducted by the U.S. Geological Survey indicates that the alluvium directly beneath the landfill has been worked as a placer. Abandoned dredgings from placer operations are still present north of the site.

According to available literature, the groundwater flow beneath the site is confined primarily to the alluvial soils. The groundwater level in the vicinity of the 12-acre parcel landfilled to date is approximately 30 to 35 feet deep, as indicated from past operations on site. Immediately north of the Burlington Northern railroad tracks, groundwater is ponded at the surface.

Potential Methane Production from the Helena Landfill

Methane production will be higher in those portions of the Helena landfill which received household refuse rather than construction debris. The disposal of liquid paint solvents and snow at the Helena facility will facilitate the decomposition of the refuse and may enhance methane production because of the added moisture content of the landfill. It is more likely that methane will be produced in the sections of the dump which were not burned earlier.

At the Helena landfill, the Y.M.C.A. and the Armory buildings, located on the inactive fill area, are susceptible to gas migration through both the natural soils and the sanitary sewer service trenches. Migration of methane to the south and southeast is restricted by compacted highway fill beneath Lyndale Avenue and Last Chance Gulch Street. However, if artificial conduits extend beneath the highway to the landfill, structures on the other sides of the embankments could also be subject to gas migration. A report by Mr. Kenneth

Waesche of the Colorado Department of Health confirms the possibility of methane migration at the Helena landfill (10). Methane migration to the west is limited by bedrock outcropping.

Current methane levels are not sufficient to support a methane recovery system. Older parts of the landfill have been oxidized by previous burning which has reduced the organic content of the fill and the methane production potential. Recovery of methane gas from landfills is not considered practical from landfill sites less than 30 feet deep. The potential for drawing air through the landfill surface during a methane recovery operation is greater on sites less than 30 feet deep (5). The depth of fill in the Helena site (12-25 feet) will not adequately support a conventional methane recovery system.

An economic feasibility study and more extensive testing will have to be completed before a final decision can be made on methane recovery from the Helena landfill. The methane gas supply does not currently appear to be dependable enough to support a methane recovery program.

Ground water Contamination from the Helena Landfill

Although landfill personnel indicated that solid waste was not disposed of directly into the ground water at the Helena site, the ground water level at the site is approximately five to ten feet below the bottom of the landfill, with pervious soils in between. Contamination of the ground water by leachate is therefore possible. Leachate production would be aided by the disposal of paint solvents and snow from city streets, which occurred during the initial years of operation of this facility.

IV. METHODS

Field Investigation

The field investigation for the project was conducted between the 8th and 12th of September, 1980. A barhole punch survey was conducted to delineate areas of gas concentrations. Seven monitoring wells were drilled and logged to test for methane and leachate. Gas monitoring equipment was placed in each well. Methane gas measurements and water samples were collected from each of the wells.

Fred C. Hart Associates of Denver, Colorado, was the principal contractor on the project. Chen and Associates assisted in the field investigations and the assessment of methane gas hazards. Rhinehart Laboratories of Denver, Colorado, performed the laboratory analyses on the gas and water samples. State of Montana officials participated in the field investigation.

Barhole Punch Survey. The barhole punch survey technique is a useful preliminary method of delineating areas of gas concentrations in order to position permanent monitoring wells (1,8). The barhole punch test consists of driving a small diameter (<1 inch), solid metal rod with a weighted sleeve to a depth of approximately three feet, removing the rod, and measuring the in-hole gas with a portable gas meter. The MSA 53 gascope was used to measure the methane. Gas sampling in each hole was done with a metal probe attached to the gascope. It is necessary to seal the hole after the metal rod is removed to prevent or reduce contamination of the gas in the hole by atmospheric gases. Dilution of the gas samples in this study cannot be ruled out. The barhole punch holes were larger than the probe and a perfect seal was impossible to maintain.

The barhole punch survey was used to determine the methane gas levels present at the landfill surface. The readings obtained during this survey were used as guidelines rather than accurate determinations of subsurface gas conditions. Several factors may affect the measurements of methane gas levels. For example, frozen ground, impermeable soils, and barometric conditions can significantly influence the subsurface gas levels. Impervious and frozen soils

and high barometric pressures tend to restrict the upward migration of landfill gas. If the barhole punch tests do not fully penetrate the confining barrier, resulting gas readings may be lower than the actual concentrations of gas within the landfill. For this reason, barhole punch surveys may not be adequate to accurately monitor landfill methane gas levels. Deep monitoring wells were drilled to obtain more accurate measurements of methane gas levels in the landfill.

Monitoring Wells. Seven monitoring wells were drilled upon completion of the barhole punch survey. Monitoring wells were located in the general vicinity of sites recommended by the Colorado Department of Health (9). Figure 5 shows monitoring well locations at the Helena site.

Monitoring wells were drilled within the boundaries of the landfill and in areas adjacent to the landfill. The wells were augered to a sufficient depth below the ground water level to obtain a representative water sample. The wells were placed at least ten feet below the groundwater level.

Wells 2, 3, and 5 were drilled slightly outside the limits of the known sanitary landfill. The primary purpose of these wells was to monitor off-site methane migration. Well 4 was drilled in the landfill mass to allow measurement of actual landfill gas generation and leachate quality. Wells 1, 6, and 7 were drilled outside the landfill mass to provide ground water level measurements and samples of possible ground water contamination. Well 1 is an upstream well and Wells 6 and 7 are downstream wells.

The wells were drilled with a truck-mounted drill rig using a 4-inch continuous flight power auger. Upon completion of drilling, a 2-inch O.D. (outer diameter) perforated PVC pipe was inserted into the hole and the annular space between the pipe and the hole was backfilled with clean sand to five feet from grade. The sand allows relatively unrestricted gas and water flow into the perforated casing. The perforated sections of the PVC pipe were prepared by cutting 1/8" wide slots in the pipe with a hacksaw. All wells used for gas monitoring purposes were designed so that the perforated sections of the wells extended above the ground water level, in order to permit gas to enter the well

casing. Each well was tightly capped after the PVC pipe was placed in the hole to exclude atmospheric gases and to allow landfill gas concentrations to collect.

The last five feet of the annular space was backfilled with bentonite clay to preclude precipitation and surface water from entering the well and prevent gas transfer into or out of the well. The top and bottom of each monitoring well were fitted with a PVC cap. A typical monitoring well cross-section is presented in schematic form as Figure 6.

Subsurface Conditions. The subsurface conditions encountered during installation of the monitoring wells are shown in Figure 7. The soils encountered were classified in accordance with the Unified Soils Classification System (12).

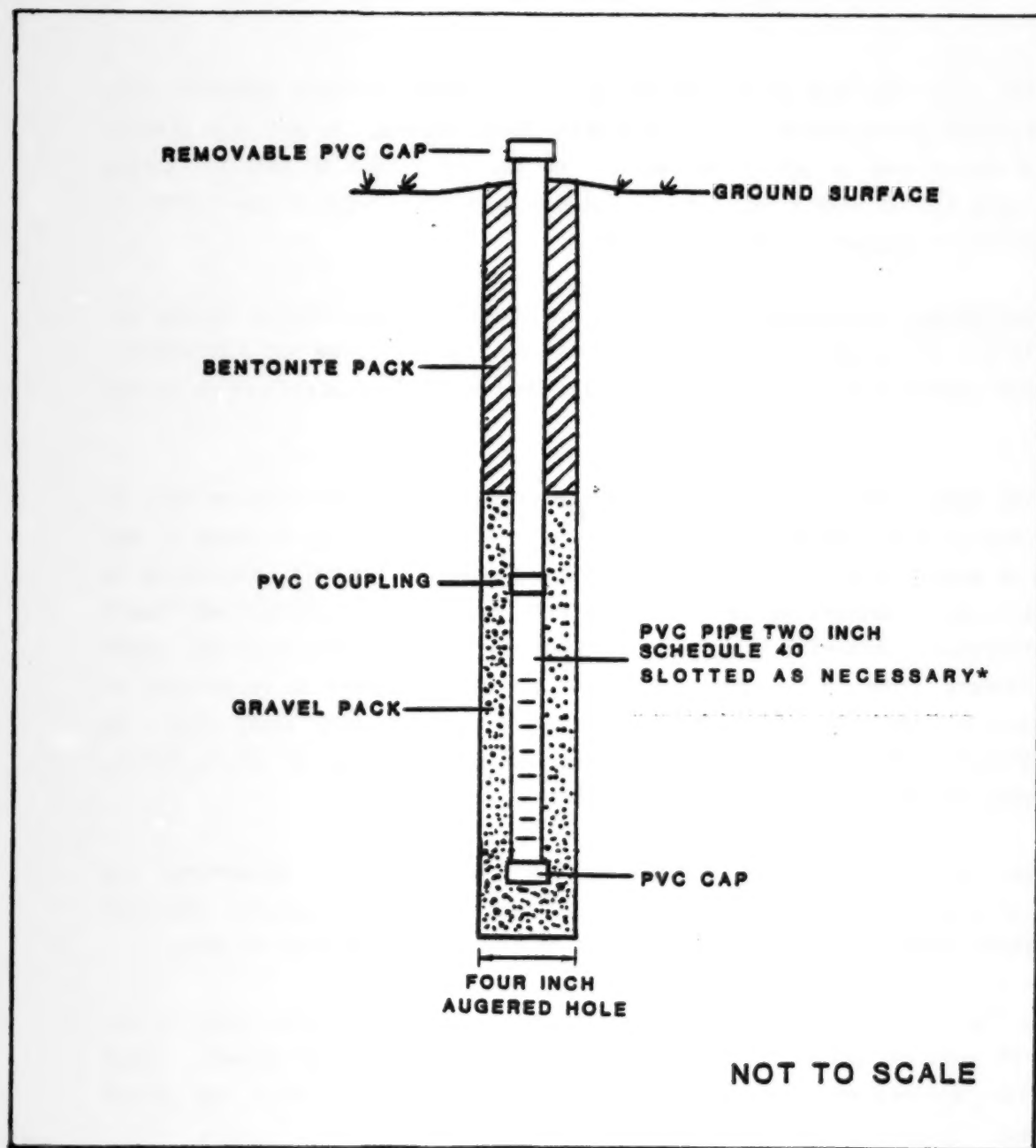
The subsurface conditions typically consisted of zero to fourteen feet of fill overlying either seven to eight feet of stiff, sandy clay or seven to ten feet of medium dense to dense, clayey sand and gravel. The fill encountered in Wells 1 and 5 appears to be associated with roadway and railroad embankment construction. This fill is composed of mixtures of clay, silt, sand and gravel and cinders. The fill encountered in Wells 2 and 3 appears to be residue of the old burning dump. This fill is primarily sandy to very sandy clay with occasional to numerous gravel and cobbles. Varying amounts of glass, brick, concrete and metal were observed within the fill.

Well 4, drilled in the inactive sanitary landfill area, encountered six feet of clay, sand, and gravel overlying 20 feet of household refuse. The wood and paper portions of the refuse appeared to have only decomposed slightly.

Wells 6 and 7, drilled north of the landfill, encountered six inches to two feet of sand and gravel fill or silt overlying clayey sand and gravel. Clean to clay sand was encountered at depths of four to nine feet below the ground surface.

Bedrock was encountered in Well 3 at a depth 28 feet below the ground surface. The bedrock is hard to very hard limestone.

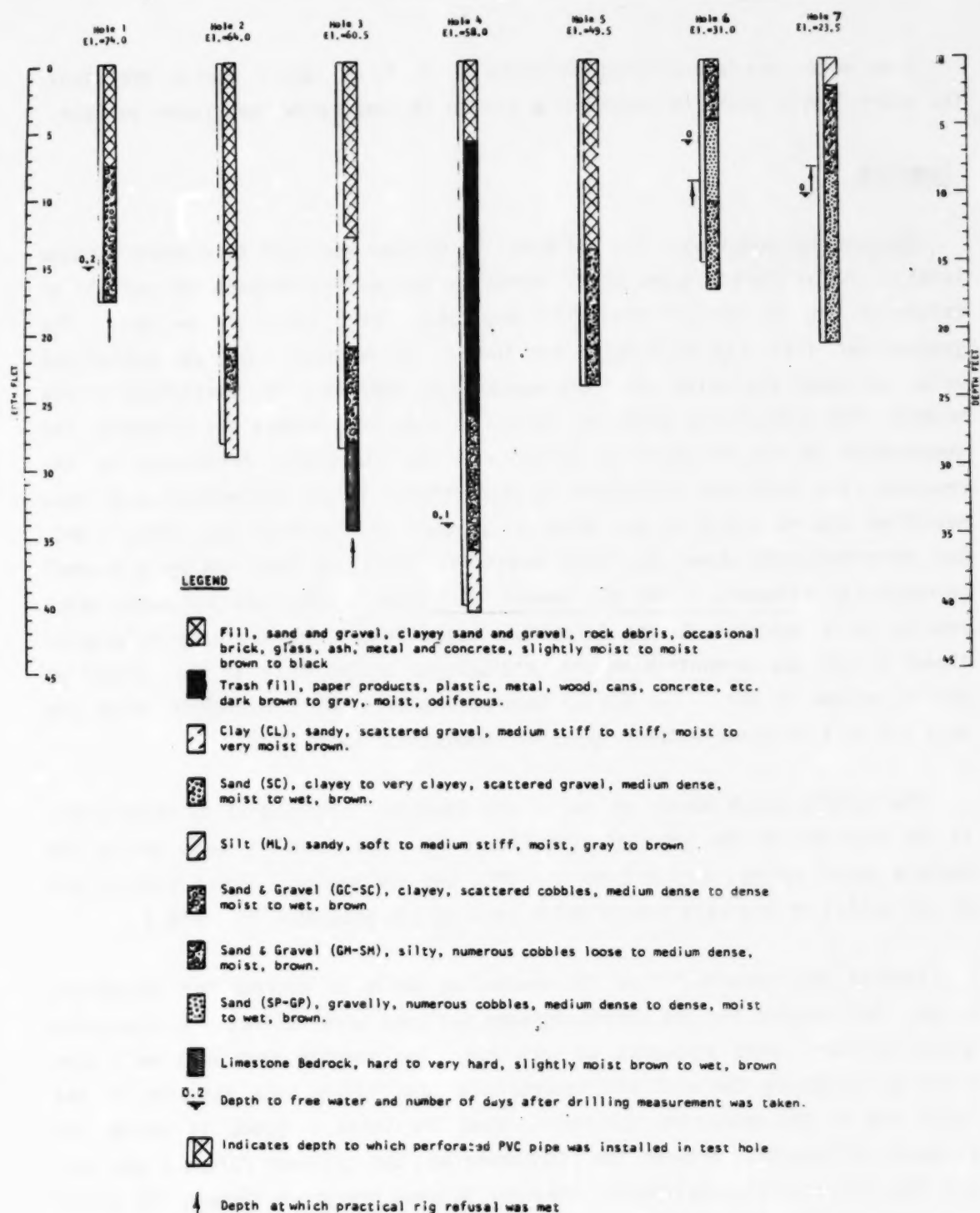
FIGURE 6. CROSS SECTION OF MONITORING WELL



Source: Fred C. Hart Associates, Inc.

* Note: The monitoring well should be slotted so that perforations will be located above the groundwater level in order to permit gas to enter the well casing.

FIGURE 7. WELL LOGS FROM THE SEVEN MONITORING WELLS PLACED IN THE HELENA LANDFILL



Notes

- (1) Test holes were drilled September 9, 10, 11, and 12, 1980, with a 4 inch diameter continuous flight power auger or 3 inch tri-cone rotary methods.
- (2) Well #5 not completed at time of initial sampling. Depth to water therefore not established.
- (3) The soil layers shown have been determined based on soil samples that were retrieved at the surface from the auger drill. The boundaries that are shown are approximate.

Free water was encountered in Wells 1, 4, 5, 6, and 7 during the study. The water levels measured ranged from six to 34 feet below the ground surface.

Sampling

Methane Gas Sampling. The MSA model 53 Gascope was used to measure methane levels. Two different types of filaments in the gascope measure the percent of volume of gas in air and the lower explosive limit (LEL) of the gas. The gascope was initially calibrated for the LEL of methane. Gas concentrations below the lower explosive limit are measured by the hot wire, Wheatstone Bridge method. The combustible gases are burned as they pass across the filament; the temperature of the filament is raised and the electrical resistance is increased. The increased resistance is proportional to the concentration of combustibles and registers on the meter as percent of the lower explosive limit. Gas concentrations above the lower explosive limit are measured by a thermal conductivity filament. The gas sample is passed across the filament which results in a decrease in the filament's resistance. The decrease is proportional to the gas concentration and is displayed on the meter as the percent of gas by volume in air. The MSA 53 Gascope measures all combustible gases and does not differentiate between types of combustible gases (1).

The barhole punch survey at the Helena landfill consisted of 23 tests within and adjacent to the landfill (see Figure 5). Gas readings taken during the barhole punch survey, inside both the YMCA and the National Guard Armory, and at the outlet of the Last Chance Gulch conduit are presented in Table 3.

Samples were obtained from the monitoring wells to analyze for subsurface gases. Gas samples for gas chromatography analyses were collected in evacuated glass cylinders with stopcocks on each end. Gas samples from each well were taken by uncapping the well and inserting a long rubber tube attached to the inlet end of the evacuated cylinder. When the inlet stopcock is opened the pressure differential between the atmosphere and the cylinder forces a gas sample into the evacuated cylinders. Several volumes are drawn through the cylinder to flush out any atmospheric gas contamination and to get a representative sample. The outlet side of the cylinder is equipped with a small, hand bellows which can be used to force air out of the cylinder if it has leaked and lost

TABLE 3. RESULTS OF GAS MEASUREMENTS FROM
BARHOLE PUNCH TESTS AT THE HELENA
LANDFILL¹

MSA MODEL 53 GAS SCOPE READINGS				
TEST LOCATION	% LEL	% GAS ²	BAROMETRIC PRESSURE	TEMPERATURE
* 1	2	1	30.48	54
* 2	1	0	30.48	54
* 3	2	2	30.48	54
* 4	3	1	30.48	54
* 5	2	2	30.48	54
* 6	2	2	30.48	54
* 7	2	0	30.48	54
* 8	2	2	30.48	54
* 9	0	2	30.48	54
* 10	2	1	30.48	54
* 11	0	1	30.45	55
* 12	0	0	30.45	55
* 13	44	3	30.45	55
* 14	0	2	30.43	57
* 15	2	0	30.43	57
* 16	2	0	30.43	59
* 17	100	14	30.43	59
* 18	6	2	30.43	59
* 19	4	2	30.43	59
* 20	54	4	30.43	59
* 21	1	0	30.43	59
* 22	2	1	30.43	60
* 23	0	0	30.43	60
* 24	2	0	30.43	60
Outlet - Last Chance Gulch Conduct	0	0	30.43	58
Bsmt - Armory - No Floor Slab	2	0	30.43	60
Bsmt - Armory - next to sewer line	0	0	30.43	60
Bsmt - YMCA - Service Corridor	2	0	30.43	66

¹ Gas composition (% volume) was not measured.

² % gas readings of 1%-2% reflect tendency of MSA 53 Gas Scope to show a slight fluctuation when activated and low readings should not be interpreted as positive indications of the presence of methane in the test holes.

its vacuum. After a representative gas sample is obtained, both stopcocks are closed and each cylinder is packed for shipment to the laboratory for analysis.

Water Quality Sampling. Ground water samples were obtained from each of the water-bearing monitoring wells installed at the site. A surface water sample was also obtained from Last Chance Gulch downstream from the site, at the point where the drainage exits from the 60-inch culvert located beneath the landfill. Figure 5 shows where each of the wells and the Last Chance Gulch sampling site are located. At the time of initial sampling, Wells 2, 3, and 7 were dry, and Well 5 had not yet been completed by the driller. Therefore, it was possible to obtain samples initially only from Wells 1, 4, and 6, and Last Chance Gulch. Approximately two days after the initial sampling date, representatives from the State of Montana Solid Waste Management Bureau (MSWMB) were able to obtain samples from Well 5 (following completion of drilling) and Well 7 (which yielded water after the two day recovery period). Since the budget allowed for the collection of two additional samples, Wells 1 and 6 were each sampled a second time by the Montana SWMB.

The ground water samples were obtained by using a galvanized steel thief-bailer well sampler. The wells were bailed to dryness and allowed to recover prior to collection of the samples. The water samples were placed in the appropriate labeled sample containers provided by the laboratory and preserved according to EPA procedures (11). Each sample container was rinsed with a portion of the sample prior to containment. The sampling progressed from the up-gradient and peripheral wells (least contaminated) to the wells in closest proximity to the site (potentially higher levels of contamination) to avoid the introduction of artificial interference from contaminated equipment. To further preclude this possibility, the sampler and attached cord were rinsed with distilled water prior to sampling each of the wells.

The pH of the samples was measured in the field using pH-sensitive test paper, accurate to within a tenth of a pH unit. All other parameters were analyzed in the laboratory within 48 hours of collection. The samples were stored in ice from the time of collection until the time of analysis.

Wells 1, 4, and 5 were selected for a scan of trace-level organics, utilizing a gas chromatographic (GC) analysis in order to detect the presence of organic solvent contamination. The samples obtained from these wells were stored in glass containers prior to analysis to preclude the leaching of low-level organic compounds from the sample containers into the samples. As with the conventional analyses, the GC scan was performed within 48 hours of sample collection.

V. DATA ANALYSIS

Methane Gas Analysis

The MSA model 53 gascope was chosen for the methane gas analysis in the barhole punch survey. The barhole punch locations can be seen in Figure 5. Results from the gascope meters for the two variables tested in the survey are presented in Table 3. The lower explosive limit (LEL) is defined as the minimum volume of a particular gas necessary to sustain combustion (with a flame source present) or the lowest point at which gas will explode if concentrated in a confined area. For this survey, the gascope was specifically calibrated for measuring methane. Therefore, a gascope reading of 100 percent LEL (e.g., test #17 in Table 3) denotes that combustible gases are present at levels greater than or equal to the five percent (5%) by volume LEL for methane. A second meter utilizing a different measurement principle is provided on the gascope as a check on the percent LEL. This meter measures the percent volume of contaminant gases in the atmosphere based on thermal conductivity instead of catalytic combustion which is the basis of the percent LEL. The percent gas meter, like the LEL meter, is calibrated for methane but actually reflects only the presence of gases other than those normally composing the atmosphere.

The actual severity of the methane problem must be gauged by evaluating and comparing the readings obtained from both meters to eliminate inherent inaccuracies of the measuring instruments. The MSA gascope always shows a slight fluctuation when the suction bulb is activated. As a result, readings of one or two percent LEL occurring concurrently with readings of one or two percent gas should be considered equal to zero. A reading of two percent gas would be reinforced by a reading of 40% LEL (when instruments are calibrated to methane where 5 percent gas = 100 percent LEL) but not by a reading of 2 percent LEL.

It must be emphasized that both meters represent indirect measures in that they are sensitive to characteristics of specific gases rather than the presence of the particular gases. The identification of the constituent gases and their relative percentages requires gas chromatography analysis.

Since the test holes showing the highest percent LEL and percent gas reading (#13, #17, #20) are located in the active landfill area, it is assumed that methane gas is present and comprises all or part of the combustible gas volumes measured.

Results from the barhole punch survey are used only to guide the placement of monitoring wells. The margin of error in measuring gas levels in a barhole punch test hole is estimated at 20-30 percent. This large margin of error makes a definitive analysis of barhole punch test results impossible. The only conclusions which can be drawn from the Helena Landfill barhole punch data are that it appears that little methane migration is occurring in the landfill and that the landfill is producing combustible gases.

The higher percent LEL and percent gas readings in test #13, #17, and #26 along the western perimeter of the active landfill indicate that some concentrations of combustible gases are present in that area. A monitoring well was not placed in the vicinity of the barhole punch test holes on the western perimeter of the landfill. Steep slopes and bedrock outcropping adjacent to the landfill will halt any methane migration on the western perimeter of the landfill. Methane produced in the active fill area either exits through the landfill cover or moves laterally in other directions.

The absence of methane in the barhole punch test holes may be caused by the shallowness of the test holes (three feet) or the low production of methane gas at the Helena landfill due to the limiting factors discussed previously in this report (temperature, air pressure, moisture, waste content). Methane gas measurements taken near or inside the structures on the inactive landfill sections do not differ appreciably from the results in the other test holes. This indicates that no methane build up is occurring in the buildings on or near the Helena landfill at the present time.

Samples were taken from the monitoring wells in order to determine the constituents of the subsurface gases. Table 4 shows the results of the MSA model 53 Gascope measurements and the gas chromatograph analyses. Concentrations of methane, carbon dioxide, and oxygen from the well samples are listed as percent of volume of gas. The initial sample showed high percent LEL and percent gas

TABLE 4. RESULTS OF GAS MEASUREMENT FROM MONITORING WELLS AT THE HELENA LANDFILL ¹

[illegible]

(MSWMB) Samples obtained for testing by Montana Solid Waste Management Bureau.

1. All samples were taken on September 12, 1980 except samples designated MSWMB which were taken during the week of September 22.
2. N₂ component was not analyzed. Gas analyses can include measurement of N₂ content, if a check to ensure the gas components add to almost 100% is needed. N₂ is about 79% of atmosphere by volume and can generally be assumed to be the remainder of the gas composition after O₂, CO₂, and CH₄ are analyzed.
3. Between the time the barometric readings in Table 3 and 4 were taken, a definitive low pressure system moved into the Helena area.

readings in Wells 2, 3, and 4. These high readings are attributed to the cement used in bonding the PVC pipe joints for the well casing. The cement gives off volatile gases as it dries. Subsequent samples taken by the Montana Solid Waste Management Bureau (Table 4 lists these samples as MSWMB) indicate that the wells have vented sufficiently to allow more accurate measurement of the gas conditions in the landfill. A comparison of the results of the gas chromatography analysis shows the discrepancy between the sample data. The second sample set indicates combustible gases in Wells 2 and 3. Well 4 was not tested a second time. Gascope readings were not taken for the second sample set.

Test results from the seven monitoring wells show that methane gas generation at the site does not appear to be in an unusually active state (see Table 4). Well holes 2 and 4 show methane gas concentrations of 1.2 percent and 8.0 percent, respectively. Measurable amounts of methane were not found in the remaining well holes. Although recent measurements by the Montana State Health Department show higher LEL values than measured during this study, methane gas generation remains minimal at the present time. A monthly monitoring program would reveal data variations caused by seasonal fluctuations, sampling procedure, or analysis methods and would yield baseline data which could be used to predict methane production trends and the potential magnitude of the methane hazards.

Varying barometric pressures will influence the gas readings in gas sampling wells. Studies have shown that the specific barometric pressure has little affect on the gas volumes in the wells. However, rising or falling barometric pressures can affect the accuracy of the gas samples' reflecting existing conditions. Decreasing barometric pressures enables the gas to move upward through the well; the gas can be measured near the ground surface. Stable or increasing barometric pressures may force gases in the monitoring wells to the bottom of the wells. Surface or near-surface gas sampling in such instances will misrepresent existing conditions. The sampling method for this report used specific barometric readings. Barometric pressures are not expected to affect the gas samples obtained in this study due to the deep sampling technique used to obtain samples from the monitoring wells.

An additional sample set from the seven monitoring wells was taken in the first week of May, 1981, by personnel of the Montana SWMB. Wells 1, 3, 6 and 7 have no gas concentrations measured. Wells 2 and 4 continue to show possibly high methane gas readings with a 6 percent (14% in a later test) combustible gas composition yielding 100 percent of the LEL in Well 2. Well 4 showed a 40 percent LEL reading (30% and 35% combustible gas composition readings). Well 5 yielded a 30 percent LEL reading. Although no conclusive results can be drawn from this single measuring effort, it is useful to note the possible confirmation of methane (or other combustible gas) in Wells 2 and 4. Additional testing and analysis are needed to corroborate these measurements; they lend added emphasis for establishing a methane gas monitoring system for the landfill site.

The organic element of the older sections of the landfill underlying the YMCA and the National Guard Armory have been oxidized by previous burning on the site. Methane generation in this section is expected to be low. The remaining portion of the inactive fill area appear to contain moderate concentrations of organic material. These materials lack the relatively high moisture contents associated with large methane production.

The unburned refuse placed in the inactive fill section between 1970 and completion of filling in 1977 has undergone a moderate amount of deterioration. The percentage of oxygen, carbon dioxide, and methane measured in the wells and the undecomposed nature of the materials in the wells supports the observation that only a moderate amount of waste decomposition has occurred. The potential exists in the inactive fill area for a significant amount of future anaerobic decomposition and methane production.

Migration. Lateral methane gas migration at the Helena landfill site appears minimal, although Well 2 indicates that some methane migration is occurring. Well 2 was drilled within ten to fifteen feet of the landfill mass. Well 3 was drilled near the YMCA building, about 50 to 100 feet outside the landfill, and had insignificant methane gas levels. No significant gas levels were measured in Wells 1, 5, 6, and 7. Well 4, drilled in the northern part of inactive fill area (near the baseball fields), shows a small amount of methane.

The granular composition of the landfill cover material may account for the absence of gas migration at the landfill. The on-site alluvial materials are probably allowing the methane to escape vertically before it is forced to migrate horizontally. Because some migration appears to be occurring in the vicinity of Well 2 and the landfill mass has continuing potential for methane gas production, an additional methane gas monitoring well should be placed between the YMCA and the Armory buildings and several barhole punch tests should be placed around the foundations of the buildings. An additional well between the two buildings would provide more conclusive information on the extent of gas migration to an area where methane might collect and explode.

Leachate Analysis

All samples were delivered to Rinehart Laboratories of Denver, Colorado for analysis. Table 5 lists the parameters which were selected for analysis in this study. The selection was made based on a review of published municipal landfill leachate characteristics (11), the recommendations of the Colorado Department of Health (10), and a budgetary review by EPA Region VIII personnel. A gas chromatograph (GC) analysis for trace-level organic compounds was also included in the study for three of the wells, based on information provided by the Montana SWMB which indicated that organic solvents had at one time been disposed of at the site.

All analyses were performed using analytical methodology specified by EPA (9), supplemented by procedures published in Standard Methods (14). The GC analysis was performed using a pentane extraction procedure recommended by Dr. Robert Rinehart (15).

Table 6 presents the results of the water quality analysis program. As can be seen from this table, two of the wells, #2 and #3, were dry at the time of collection and samples could therefore not be obtained. Wells 1 and 6 were each sampled twice (within a three day period), since budget constraints allowed the collection of two additional samples.

The results of the analyses indicate that the Helena landfill is not posing any major hazard as a result of leachate migration. In Table 6, the water quality results are compared against three sets of published values for inter-

TABLE 5
PARAMETERS USED IN THE HELENA LANDFILL STUDY

Parameters used in the Helena Landfill study.

1. pH
2. Specific Conductivity
3. Total Dissolved Solids
4. Total Alkalinity
5. Chemical Oxygen Demand
6. Nitrate-Nitrogen
7. Sulfate
8. Sodium
9. Potassium
10. Cadmium
11. Zinc
12. Copper
13. Nickel
14. Chromium
15. Lead

TABLE 6. RESULTS OF THE CHEMICAL ANALYSES

PARAMETER	Well 1 Sample #1	Well 2 Sample #2	Well 3	Well 4	Well 5	Well 6 Sample #1	Well 7 Sample #2	Well 8 Last Change Switch	Drinking Water Standards	Water Quality Criteria 2	Range in Concentration in Natural Environment 3
PH	6.0	7.0									NA
SP. CONDUCTIVITY (MHMS/CM)	840	900		1270	1500	1200	1070	670	380	NA	NA
TOTAL DISSOLVED SOLIDS (mg/L)	423	720		1035	1273	883	970	396	309	500	NA
TOTAL ALKALINITY (mg/L)	229	272		282	579	294	295	181	153	NA	10 - 7000
COD (mg/L)	153	456		281	149	101	92	125	82	NA	NA
NITRATE-N (mg/L)	4.45	4.74		12.8	0.20	12.0	7.15	1.08	1.14	10	.01 - 10
SULFATE (mg/L)	218	227	DRY	264	417	279	274	100	35	250	1 - 1000
SODIUM (mg/L)	32	27	DRY	40	55	35	29	22	5.0	NA	1 - 1000
POTASSIUM (mg/L)	9	8.8		13	9	3	5.5	3	1.6	NA	.01 - 10
CADMIUM (mg/L)	0.0029	0.0006		U. 0.010	U. 0.003	0.0017	0.0005	0.0007	0.010	0.010	.001 - 0.1
ZINC (mg/L)	0.74	0.45		U. 0.057	U. 0.01	0.15	0.0049	0.20	0.15	5	.001 - 0.1
COPPER (mg/L)	0.049	0.013		U. 0.0037	U. 0.011	0.39	0.0010	0.037	0.0036	1	.001 - 0.1
NICKEL (mg/L)	0.0066	0.0009		U. 0.008	U. 0.022	0.0006	0.0036	0.0074	0.77	NA	.001 - 0.1
CHROMIUM (mg/L)	0.017	0.014		U. 0.014	U. 0.015	0.017	0.012	0.018	0.015	0.05	.001 - 0.1
LEAD (mg/L)	0.011	0.14		0.043	0.024	0.023	0.042	0.042	0.080	0.05	.001 - 0.1

- 1 US EPA, National Interim Primary Drinking Water Regulations, EPA-570/9-76-003, U.S. GPO, Washington DC, July 1976. National Secondary Drinking Water Regulations, Federal Register, 44FR42195, July 19, 1979.
- 2 U.S. EPA, Quality Criteria for Water, U.S. Government Printing Office, Washington DC, July, 1976.
- 3 Davis, F.N., and J.M. Dewest, Hydrogeology, John Wiley & Sons, NY, 1966, as cited in: U.S. EPA, Procedures Manual for Ground-Water Monitoring at Solid Waste Disposal Facilities, EPA/536/SM-611, 1977.

pretative purposes. These comparative values include the EPA Primary and Secondary Drinking Water Standards (16), the EPA Water Quality Criteria (17), and published values for those constituents which occur in natural ground water (18). This comparison indicates that the ground water in the vicinity of the site has not been altered significantly by the existence of the landfill. None of the values greatly exceed any of the published values, although the dissolved solids content of the samples generally are higher than the EPA drinking water standard of 500 mg/l. Samples from two of the wells, numbers 4 and 6, showed elevated levels of nitrate. Both samples showed nitrate-N concentrations of 12 mg/l., which is slightly above drinking water standard of 10 mg/l. Wells 1 and 7, and Last Chance Gulch, also showed elevated levels of lead, above the EPA drinking water standard of 0.05 mg/l. The high lead value from well number 1 located upgradient from the site, may be attributable to analytical error, since the anomalously high value of 0.14 mg/l. was observed for only one of the two samples obtained from that well. The other sample showed a lead value of 0.011 mg/l., an order of magnitude below the former samples. Further sampling and analysis will be needed to clarify this discrepancy. The lead values obtained from the wells sited within the landfill were below the EPA drinking water standard.

Although the dissolved solids content of the samples indicates that the ground water in the vicinity of the landfill (both upgradient and downgradient) is generally not potable, the range of values observed for the monitoring wells still fall within those expected for natural ground water. In summary, the comparison of the sample values with published water quality information indicates that the ground water has generally not received any of the measured constituents from the landfill at levels which would provide cause for alarm. However, the ground water is not considered potable due to elevated levels of dissolved solids, and possibly nitrates and lead.

In addition to comparing the results of the water analyses to published water quality information, the significance of leachate contributions to the ground water of the area can also be assessed by comparing the water quality characteristics of the background (upgradient) well with the characteristics of the downgradient wells. In this case, the water quality observed for Wells 6 and 7, downgradient from the landfill, was generally as good as that observed

for Well 1. Wells 4 and 5 are sited within the landfill boundaries; typically, they should have poorer water quality characteristics than the downgradient (off-site) wells. This trend was not observed to a significant degree at the Helena landfill. The fact that ground water beneath the landfill site (as indicated by wells 4 and 5) does not contain significantly elevated levels of constituents (relative to either the upgradient or downgradient wells) indicates that large volumes of leachate are probably not being generated in the landfill.

Trace-Level Organic Compounds. The gas chromatograph analysis of the water samples obtained from Wells 1, 4, and 5 showed no detectable organic constituents. Dr. Robert Rinehart confirmed that the GC scan employed was of sufficient scope to detect any organic solvents in the samples which may be present as a result of the disposal of paint solvents in the landfill (15). The scan would be able to detect compounds present in the sample in the microgram/liter (parts per billion) range if indeed they were present. As a result, the solvents which were reportedly disposed of in the Helena landfill pose little danger to the environment at this time. Further analyses may be required in the future, however, to verify that the conditions have not changed and to confirm that a leachate plume containing organic solvents has not been generated.

Direction of Ground water Flow. The direction of ground water flow in the vicinity of the Helena landfill site can be established by plotting the water table elevations (relative to an arbitrary datum) observed in each of the monitoring wells. Table 7 shows the elevation of the water table in each well, relative to the ground surface at the top of Well 1 (the assumed arbitrary datum in this study). The ground surface at Well 1 is arbitrarily assigned an elevation equal to zero.

Based on this information, the direction of ground water flow in the vicinity of the Helena landfill is from south to north, following the general slope of the land surface. In this area, the ground water should also be in hydraulic connection with Last Chance Gulch, which also flows to the north.

The reason for the temporal variation in ground water levels near the landfill is unknown at this time; further long term monitoring of water levels would be required to establish this variation. It is possible that the ground

TABLE 7

WATER TABLE ELEVATIONS

<u>WELL NUMBER</u>	<u>ELEVATION*</u>	<u>DEPTH TO WATER</u>	<u>WATER SURFACE ELEVATION*</u>
1	0.0 ¹	15'	-15'
2	-10.0 ¹	Dry	N/A
3	-13.5 ¹	Dry	N/A
4	-16.0 ¹	34'	-50'
5	-24.5 ¹	Not Established**	N/A
6	-43.0 ¹	6'	-49'
7	-50.5 ¹	10'	-60.5'

* All elevations are in reference to well number 1, which is arbitrarily assigned an elevation equal to zero.

**Well not completed at the time initial measurements were made.

water levels in the vicinity of the landfill could vary in direct response to individual precipitation events. The direction of flow is topographically controlled and will not change.

It is also important to realize that the water levels recorded in this study were those present shortly after drilling; the ultimate levels could deviate from these values following further recovery of the wells.

During certain times of the year, it is possible that Last Chance Gulch may serve as a source of recharge to the ground water system in the vicinity of the landfill. This would occur under those circumstances where the water levels in the wells were below the stage elevation of Last Chance Gulch. During the remainder of the year, the ground water would ultimately discharge to the Gulch, serving to maintain base flow in the channel. In order to precisely define these relationships long-term monitoring of water levels in the wells would be necessary.

Statistical Significance of the Data

It is important to realize that the above discussion is based on the results of a single sampling effort which has little statistical significance. These conclusions must be viewed with caution, since the variability in the data, for the most part, has not been established. For example, Wells 1 and 6 were each sampled twice during the three day field investigation, and the results for these wells indicate that the ground water quality can vary. These variations can result from natural fluctuations in the ground water quality, from the introduction of artificial interferences such as sampling error, and in the range of accuracy expected for the analytical procedures.

In order to fully determine trends, long term averages, seasonal fluctuations, and ranges in concentration of ground water and methane for each of the wells, monitoring must be continued over a longer period of time. A number of data points for each well would allow a statistical comparison of the water quality and methane levels which exist at each monitoring location. The statistical significance of the data cannot be determined from a single set of samples.

We can conclude based on the single set of data points, that the Helena landfill does not pose an immediate risk to the environment or general public. No ground water contaminants were observed at any levels which would classify the landfill as an "imminent hazard," as defined by Section 7003 of the Resource Conservation and Recovery Act. Methane levels were also not considered hazardous. This is the most important conclusion which can be drawn from the initial sampling and analysis program.

VI. CONCLUSIONS AND RECOMMENDATIONS

Methane Gas Generation

Conclusions. Preliminary findings indicate that:

- o A minimal amount of methane is currently being generated within the inactive landfill area.
- o The migration of methane appears minimal.
- o Current methane production is not sufficient to support a dependable, long-term methane recovery system.
- o An automated methane monitoring alarm system should be installed in the Helena YMCA and the National Guard Armory.

Some methane gas concentration occurs along the eastern edge of the inactive fill area. As a precautionary measure, it is recommended that additional methane monitoring wells should be drilled between the YMCA and the Armory buildings to assess the potential methane concentrations in this area.

Although methane migration at the Helena landfill does not appear extensive, it is possible that concentrated pockets of methane may exist in the landfill. Current data does not support this conjecture, however. A more thorough well drilling and monitoring program would be necessary to establish the likelihood, if any, of this potential.

Methane concentrations are not dangerous (and barely detectable) within and adjacent to the landfill site. Methane levels are not expected to increase appreciably in the near future.

It may be prudent, however, to construct impermeable barriers to control methane migration where possible in the active fill area. While the data do not indicate alarming levels of methane in or adjacent to the landfill, the proximity to residential or recreation areas would dictate taking precautionary measures where possible to control potential methane migration. Additionally, the future fill site design might include impermeable barriers or an effective ventilation system around the site perimeter.

The absence of substantial methane migration at the Helena landfill is probably due to the granular nature of the landfill cover. The alluvial materials on the site appear to allow any methane gas produced in the landfill to exit vertically without forcing the methane to migrate laterally. Although no methane control measures are currently in place at the landfill, the continued placement of organic refuse in this area will result in future methane gas generation in the landfill and a potential off-site methane migration problem east of the landfill.

Recommendations. Gas readings with a MSA Gascope should be taken on a monthly basis in Wells 2, 3, 4. Additional monitoring wells should be drilled around each building and further barhole punch testing done near the foundations of the YMCA and the Armory (See Figure 5 for recommended locations). Seasonal gas readings should also be taken in the service corridor of the YMCA building and in the basement of the National Guard Armory building by the local gas company with a flame pack or more sensitive device. These readings should be taken during extreme seasonal conditions such as during hot summer period shortly after a heavy rain, when the ground is frozen in the winter, and during the spring runoff period. Additionally, readings in the buildings should be taken at times when the surrounding monitoring wells indicate high levels of methane. Sufficient baseline data could be established by seasonal flame pack and monthly readings over a two year period. Methane gas migration control systems could be installed in the landfill based on the analysis of this data.

Installation of an automated monitoring and alarm system in the YMCA and the Armory is also recommended. The YMCA and Armory buildings should be monitored closely during the winter months since building doors and windows are closed during the winter months. Frost reduces the vertical ventilation of gas in the landfill and greater horizontal methane migration is possible.

The costs for additional drilling of monitoring wells and installations of a methane alarm system for the YMCA and Armory buildings are estimated below. Well development costs are estimated to be about \$500 per well which includes drilling, logging, and installation. The seven wells used for this study averaged about \$570/well. The probable cost range for developing each well is between \$400 and \$650. These estimates include the use of a well-drilling rig

for four hours at \$60/hour, an engineer/logger for 4 hours at \$25/hour, and mountings for about \$100 (for a 30 foot well). The severity of the drilling conditions at the Helena site limits the use of an auger because of the rock and gravel deposits and increases the expense of the drilling operation.

The cost to install a methane alarm system in the YMCA and Armory buildings is estimated to range between \$2,000 and \$4,500, depending upon whether a combined or separate alarm system is used. The central panel and four monitors of a combined alarm system cost about \$2,000. Additional monitors each cost between \$400 and \$500. Six to eight monitors are expected to be needed for the YMCA and the Armory. These monitors should be located based on the results of the flame pack analysis. The central panel could be located in either building, although an Armory location may be easier to monitor. Placement of remote monitors should not exceed 1,000 feet from the central panel due to the resistance to the signal impulses over long distances. The local fire department should be informed regarding the operation of the methane alarm system.

Leachate Contamination

Conclusions. The primary conclusion which can be reached concerning the leachate contamination potential of the Helena landfill is that the landfill poses no immediate hazard to the environment or the general public. The water quality analyses performed on the water samples obtained from the site indicate that there is little difference in the constituent levels present in the down-gradient wells, relative to the upgradient (background) well. Furthermore, the wells sited within the landfill body showed comparatively little significant increase in constituent levels, although dissolved solids and specific conductivity were slightly above those observed for the background well. Generally, the constituent levels for all the wells were within the ranges expected for natural ground water. Although the constituent levels were low in comparison to published values, the ground water quality is probably not potable, due to elevated levels of total dissolved solids and to the absence of long range water quality testing.

The gas chromatographic scan of three water samples from the site also indicated that low-levels of organic solvents are not present. The scan was comprehensive in scope, and would have detected the presence of industrial paint solvents, reportedly disposed of at the site, if they had entered the ground water in significant quantities near the wells.

The overall conclusion that the landfill poses no immediate health or environmental hazard must be viewed with caution, since the conclusion is based on a result of a single set of sampling points only. Statistically, it is not possible to determine the variability which may exist in the data for each well, since additional data points, obtained through additional monitoring efforts, would be necessary. This information would also be required before subtle, yet discernible, trends could be distinguished. The initial set of sampling points indicates that the landfill does not constitute an immediate health or environmental hazard, since extensive, off-site leachate migration was not observed.

Recommendations. It is recommended that the State of Montana Solid Waste Management Bureau institute a long term water quality monitoring program at the Helena landfill site. The program should involve the collection of water samples from each of the water-bearing wells installed at the site, as well as from Last Chance Gulch, both upstream from the site and at the point of exit from beneath the landfill. Water-level measurements should also be made at each of the wells. It is anticipated that a quarterly sampling program will be adequate; however, the sampling schedule should be flexible, allowing for modification should the results of the program dictate the need for either an increase or a decrease in sampling frequency. If the results of the quarterly program substantiate that leachate contamination is not significant, the program could be reduced further to sampling on either a semi-annual or annual basis. However, it is important that the program be instituted soon so that additional data can be obtained to validate the conclusions drawn in this report. The observed elevated levels of nitrate and lead further substantiate the necessity of a monitoring program.

It is recommended that the ground water monitoring program initially include all the test parameters contained in Table 5 of this report. This would verify the statistical significance of the conclusions presented. However, depending on budget considerations, a reduced set of parameters may be considered. A reduced set could consist of the following key parameters suggested by EPA (10):

- o Specific Conductance
- o pH
- o Temperature
- o Chloride
- o Iron
- o Color
- o Turbidity
- o COD

plus the addition of:

- o Nitrate - N
- o Lead

Nitrate - N and lead were observed in some of the wells at values above drinking water standards.

By utilizing a reduced set of parameters, a substantial cost savings in analytical work can be achieved. The above analyses would typically cost about fifty dollars (\$50) or less per sample. However, if a sudden change in an indicator parameter is observed, it will require extended analytical work. Extended analyses are necessary to pinpoint the limits of the possible contamination.

In addition to the limited list of conventional parameters considered above, it may also be beneficial to include a GC scan on an annual, or semi-annual, basis to ensure that a solvent-laden leachate plume from the disposed solvent drums has not entered any of the wells. The initial data indicates that trace organic compounds do not pose a major problem at this time.

If the results of the long term program at any time indicate that extensive off-site migration of leachate is occurring, additional test parameters should be added to fully define the magnitude of the problem. Tables 1 and 2 will be useful for determining the other constituents which may have to be tested. If a problem is identified through long-term monitoring, the program should be amended to include as many as possible of the pertinent leachate constituents.

Although the initial program did not reveal any significant health or environmental problems resulting from leachate generation at the Helena landfill, the institution of the long-term monitoring program is recommended for the following reasons:

- o to generate enough data so that stastically valid conclusions can be made.
- o to observe subtle trends in ground water quality, observable over long periods of time, which would indicate that discernible leachate migration is occurring.
- o to identify seasonal trends in ground water levels and direction of flow.
- o to verify that a leachate plume does or does not exist within the Helena landfill.

We recommend that the City of Helena and the State of Montana implement a long-term methane and leachate monitoring program at the Helena landfill site in order to assemble the necessary baseline data.

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